ISSN 0348-3908

UPPSALA PSYCHOLOGICAL REPORTS

NO. 369, 1984

THE DETECTION AND LOCALIZATION OF OBJECTS BY THE BLIND WITH THE AID OF LONG CANE TAPPING SOUNDS

BO SCHENKMAN GUNNAR JANSSON

UNIVERSITY OF UPPSALA

HV1708
Sch27

DEPARTMENT OF PSYCHOLOGY · UNIVERSITY OF UPPSALA · SWEDEN

M.C. MIGEL LIBRARY
AMERICAN PRINTING
HOUSE FOR THE BLIND

THE DETECTION AND LOCALIZATION OF OBJECTS BY THE BLIND WITH THE AID OF LONG CANE TAPPING SOUNDS

Bo Schenkman and Gunnar Jansson

University of Uppsala

Sweden

Please address communication about this prepublication to:

Department of Psychology
University of Uppsala
Box 227
S-751 04 UPPSALA
Sweden

HV 1708
Sch 27
Copy one

Abstract

The aim of the investigation was to study the usefulness of long cane tapping sounds for echolocation by blind people. Ten long canes which differed in the spectra of their tapping sounds were selected for the experiment. The task of the three blind subjects when walking was first to detect an object and then to localize it more precisely. The distances between observer and object were measured at the moment the subject indicated detection and localization, respectively. The following results were obtained. (1) Objects could be detected and localized with the aid of long cane tapping sounds alone, but the task was difficult. (2) The results varied with the size of the object. (3) Differences in the spectra of tapping sounds had no behavioral effects, and therefore no relation between behavior and sound spectra could be determined.

Introduction

Sighted man detects and localizes objects in the environment mainly by vision and to a certain extent by hearing, touch and smell. When vision is lacking, however, the latter perceptual systems have to carry the whole burden of obtaining information about the environment. For the blind person the task of perceiving the existence and location of objects at a distance is taken over especially by the hearing system. Auditory information is available not only about sound sources but also about surrounding objects reflecting sound. As shown by the classical studies by Dallenbach and his associates (Supa, Cotzin & Dallenbach, 1944; Worchel & Dallenbach, 1950; Cotzin & Dallenbach, 1950; Ammons, Worchel & Dallenbach, 1953) reflected sound is the main source of information used by the blind for the detection and localization of objects.

It is somewhat surprising that man has the ability of such a use of sound, i.e. echolocation, as sighted man has no known important use of it (Griffin, 1977). In contrast to several animal species, especially bats and dolphins, man has not adapted his vocalizing or auditory organs for this special function (cf. e.g. Ayrapetyants & Konstatinov, 1970). One effect of this is that man can not reach the high efficiency for echolocation that is possible for bats.

However, within the range of human capacity, the blind person often learns to use many different kinds of sounds for echolocation. Many of these are self-produced sounds, such as vocal sounds and sounds created by hand clapping, foot scraping and long cane tapping. The present study is concerned with the tapping sounds produced by long canes.

Available and useful stimulation for echolocation

The physical basis for echolocation is that a sound, produced by the observer or some environmental sound source, is reflected by surfaces in the surroundings. At the observer's ears both the original sound and its reflections are available. The information about the existence of a sound reflecting object and about its distance and direction to the observer's position may be available in the reflection alone or, jointly, in the original sound and its reflection.

In a dynamic situation where distance is changing the Doppler pitch effect is also available. Cotzin & Dallenbach (1950) proposed this as the explanation of the perception of obstacles by the blind. There are also differences in intensity depending on distance, this variable being a better candidate for providing the useful information according to Twersky (1951), who based his argument partly on the fact that echolocation is possible also in static situations. These two early explanations of human echolocation did not distinguish between a situation when the human auditory system fuses the original sound and its reflection into one perceived sound and a situation when it separates them from each other.

The information available in the reflection alone, i.e. the echo, is of the same kind as the information available in the sound from a sound source located at a distance from the observer. There are physical properties informing about direction, such as differences in interaural level and phase, but also information about distance, at least relative distance. A review of the factors that determine auditory localization is given by Mills (1972).

Information about distance is available in the joining of the original sound and its echo. The time difference between corresponding parts of the original sound and its echo changes with the distances between source, reflecting surface and observer. When the time intervals are below a certain threshold (at distances between object and observer, under the present conditions, shorter than about 2-3 m) the two sounds are not perceived separately, but merge into one auditory phenomenon. The mechanism underlying this has been analysed in different ways, as time separation pitch (Thurlow & Small, 1955; Small & McClellan, 1963), repetition pitch (Bilsen, 1963; Bilsen & Ritsma, 1970) and ripple noise pitch (Yost, Hill & Perez-Falcon, 1978). Bassett and Eastmond (1964) made an important study where they showed that the pitch which is perceived by the blind at short distances, is a function of the distance between the person and the reflecting object.

When the time intervals are long enough (at distances between object and observer longer than about 2-3 m) two distinct sounds are perceived, the sound source and the reflected sound. The latter has been called an acoustic image (Wilson, 1967).

The intention of this short survey of the available and useful information for echolocation was not to go into the subtleties of the ongoing theoretical discussion, but to indicate the richness of the available information and that some of this information may be useful for human beings.

One interesting question in the present context, i.e. the usefulness of long cane tapping sounds, is the possible importance of the spectral content of the auditory stimulation, which apparently differs between

canes. According to some investigators studying situations when the time interval between the original sound and its repetition is small, the spectral content is important. It should be within 200 - 2000 Hz according to Bassett and Eastmond (1964) and above 1000 Hz as suggested by Fourcin (1965). On the other hand, Wilson (1967) argues that the spectral content is unimportant.

Problems

In a natural situation the long cane tapping sounds are available together with many other sounds. It is not obvious that they are useful in themselves. The first problem to be studied is therefore whether objects can be detected and localized solely with the aid of long cane tapping sounds.

The intensity of the reflected sound depends on the size of the reflecting object. A second problem is therefore the effect of the size of the objects to be detected and localized.

The efficiency of the sounds may vary with their properties. There are great differences between the sounds produced by different long canes, e.g. in their spectral content. A third problem chosen here is to examine if walking with long canes differing in tapping sounds mean any difference in the detection and localization of objects.

Finally, a fourth problem of the long cane sounds concerns the relation between the behavioral data and the physical properties of the sounds. Given differences between long canes in their efficiency in aiding the blind to detect and localize objects, how are these differences related to the spectral content of their tapping sounds?

Method

Choice of long canes

The tapping sound depends on several properties of the long cane, such as its elasticity, number of parts, kind of joints, and kind of tip. It is a short sound. According to measurements described in the Appendix most cane tapping sounds of the kind studied here had the main part of their energy in a time interval lasting from 5 to 10 msec. For the experiment a representative sample of canes was wanted, and therefore the sounds from a great number of long canes were analysed.

Measurement of sound spectra. A chamber made of sound-absorbing material, the Swedish Gullfiber, was constructed inside an ordinary large room. Gullfiber is a mineral-wool consisting of long glassfibres merged together, made by the TEL-wool-process patented by Saint-Gobain in France. It has acoustic properties very similar to the stone-wool Rockwool-material, but generally less Gullfiber is needed to produce the same sound-absorbing effect as a certain amount of Rockwool. In our tests it had a thickness of 50 mm. The walls and floor of the chamber were covered with this material, as were the upper corners of the roof. The base of the chamber were 3.3 x 3.3 m and its height was 2.07 m. The ceiling of the ordinary room, in which this chamber was situated, was clad with regular sound-absorbing plates. A person performed the tappings with the canes standing on a fixed place halfway from each sidewall of the chamber and .5 m from the back wall of it. There was a free area, .30 x .56 m, 1.5 m in front of him, on which he tapped the cane. Behind this tapping area, as seen from the person doing the tapping, a 1/2 inch condensor microphone (Bruel and Kjaer, type 4134) was positioned. It was placed .6 m above ground and .3 m away from the

tip of the cane. Gullfiber plates were also laid out in front of the support for the microphone (see Figure 1).

Insert Figure 1 about here

The signals from the microphone were preamplified (Bruel and Kjaer Cathode amplifier, type 2615) and then fed to Bruel and Kjaer Digital Frequency Analyzer, type 2131. The result of the frequency analysis was finally fed to an xy-writer, Houston Omnigraphic 2000 recorder.

The averaging time for integration of signals was 1/32 sec, as a record of the fast transients of the signals was wanted (see also Appendix). Filter bandwidth was 1/3 octave and frequency range recorded was 25 - 20000 Hz. The octave bands below 250 Hz were not utilized in subsequental analyses, primarily because of the internal low noise in the room; but also because of the low sensitivity of the human ear to low frequencies at small amplitudes. The frequency analysis was performed on nonweighted dB levels.

The floor was made of heavy concrete covered by linoleum glued to it, which was the same kind of floor as in the room where the subsequent behavioral measurements were made.

The person performing the tappings stood on the assigned place in the chamber and let the cane fall twice onto the tapping area. The cane was held lightly in the hand, between the thumb and index finger. The handling of the cane may be said to have been fairly undamped. After it had touched the material twice, it was forced not to tap again. The frequency analyser was put in a max hold mode. This mode holds the

maximum levels in each 1/3 octave making it possible to record them on the XY-writer. The angle between ground and cane when touching ground was approximately 45°.

It is important to note that the setup for the measurement of the sound-spectra of the canes in the sound-absorbing chamber was not meant to give absolute values on the measured acoustic dimensions. To obtain such data an anechoic room should have been used. The aim was to obtain reliable values that could be used in comparisons of the sound-signals of the canes and in the establishment of the relationships between the physical and the behavioral tests. For these purposes relative values of the sound-spectra can be considered sufficient. However, the linearity between the spectral analysis performed with different integration times (see Appendix) indicate that if the measurements had been made in an anechoic room, the results would probably had differed very slightly from the results obtained in the sound-absorbing room.

The same person performed all the tests of the physical characteristics of the canes, as the reliability over persons and over time had been shown to be very high (see Appendix, where also studies of the effect of different handgrips and incident angles are described).

Methods of choice. The original sample of long canes consisted of 32 canes from Sweden, Denmark, Great Britain, West Germany and the U.S.A. These canes were acoustically analysed as described above, and a smaller sample of 10 canes was chosen on the basis of two main ways of comparing the spectral data. The first method was the forming of hierarchical cluster schemes by the minimum method (Johnson, 1967), 20 of the 1/3 octave frequency bands comprising the variables. The second method of analysis was based on a plotting of the deviations for each cane from

the average Sound Pressure Level (SPL) of all canes over each frequency band. The first method put similar groups of canes into hierarchical clusters, and the second method made it possible to examine the spectra in more detail. The latter method was also expected to reduce the effects of possible resonance qualities of the room wherein the sound-absorbing chamber was situated.

The final selection of canes was based on a combination of the two methods with the purpose of making the 10 canes chosen as different as possible on the basis of both the hierarchical clusters and the frequency bands. As the original sample probably comprised a majority of the mostly used long canes in the world, the final sample may be considered as reasonably representative of all the presently used canes, at least from the point of view of their frequency spectra. The mean SPL values of all the 32 canes in each 1/3 octave band is given in Table 1. The 10 canes chosen for the experiment are described in Table 2 and their deviations from each mean SPL are depicted in Figure 2.

Insert Tables 1 and 2 and Figure 2 about here

Experimental arrangement

The experimental arrangement was similar to that used by Jansson (1975) and Jansson and Schenkman (1977). The experiment was conducted in a large room (24 x 15 m). In the middle of this room a .5 m wide carpet was laid from one wall to the other, in order to guide the pedestrian in his walking. Along the carpet were four racks, each consisting of 2.3 m high, thin vertical bars placed at 3.4 m apart from each other at each side of the carpet and mounting a horizontal bar.

These racks were placed at 7, 11, 15 and 19 m from the starting point.

From the vertical bar of one of these racks an obstacle in the form of a 1 mm thick white cardboard was hanging in thin nylon strings (see Figure 3). The midpoint of the obstacle was positioned vertically above the middle of the carpet 1.44 m from the floor. Four sizes of obstacles were used: 1.50, .75, .38. and .19 m^2, width and height being 1.46 x 1.03, .73 x 1.03, .515 x .73, and .365 x .51 m respectively.

Procedure

There were two identical experimental sesssions, each containing 50 experimental trials. Before these trials there were five training trials (or a few more if the subject was uncertain concerning his/her task) performed with the subject's own cane. The 10 experimental canes were then used in a random order which was different for each subject. For each cane a block of five trials was performed, one trial for each obstacle size and one blank trial without any obstacle, all trials within the block in a random order different for each block. In the blank trials the time taken for the subject to walk the full distance of the path along the carpet was recorded to get a measure of his or her walking speed. The mean walking speeds for the three subjects were .4, .5 and .8 m/s, respectively.

The subject was not told which cane he or she was given, or if the trial was blank or not. In the trials with an obstacle he/she did not know its position as the four racks were used in a random order. Nor did he/she know that there were four racks.

In order to avoid any visual information all the subjects wore a blind-fold. In order to mask any unintended sound information related to

the position of an obstacle music was played from a tape-recorder during all intermissions for the mounting of the obstacles. No mounting was begun before the subject had returned to the starting place. The subject was told to try to detect and localize obstacles along the path with the sole aid of the sounds from the cane when tapped. He/she walked in his/her socks along the guiding carpet tapping outside it on the linoleum floor with the cane (see Figure 3). As soon as the subject detected an obstacle he/she should indicate this by letting a specially prepared paper-ball fall silently onto the floor. This is called the detection phase. For closer localization he/she should then approach the obstacle as close as possible without colliding with it. When he/she had moved as close as he/she could, he/she should point with a finger to his/her nose and stay until the distance between his/her nose and the obstacle was measured. This constitutes the localization phase.

Each experimental session lasted two to three hours with a break after half the session. The second session was arranged in the same way as the first one, except that new randomizations of canes, obstacle sizes, and obstacle positions were used.

Insert Figure 3 about here

The dependent varables. The two variables measured were the distances for detecting and localizing the objects. These were essentially the same as those used by Dallenbach and his associates (cf. above), even if their terms were different ("first perception" and "final appraisal", respectively).

The detection distance indicates the usefulness of the tapping sound for detecting the existence of an object in the direction of walking, a longer distance meaning greater usefulness. A collision with the object was set equal to zero.

The second variable was intended to have another character, viz. to be a kind of precision measure. A special problem concerns the treatment of the collisions in the case of localization distances. In the non-collision cases a smaller value indicates a higher precision. If a collision were given a value of zero, this would then falsely indicate that the subject was very precise in localizing the object. In order to make all the values of the second variable meaningful, the localization distances (in meters) were inverted, except for the collisions which were set equal to zero. This variable was called inverted localization distance. A high value now indicates that the observer got close to the object without colliding with it, and a low value indicates a low precision, caused either by the observer stopping far from the object or by colliding with it.

Subjects

Three blind persons acted as subjects. Subject No. 1 was a woman, 46 years old, with Retinitis Pigmentosa from birth. Subject No. 2 was a 24 year old woman who had been blind for 6 years because of Diabetes. Subject No. 3 was a man, 32 years old, who had been blind since the age of 13 because of tumor growths on both retinas. Subject No. 1 has some minor light awareness, while the other two were totally blind. All three subjects used the long cane as their main mobility aid and they were judged by mobility instructors to be good cane travellers.

Audiometric tests demonstrated that the subjects had normal hearing with thresholds less than 20 dB from the standard threshold for the frequency range 125 - 8000 Hz.

Two more subjects took part in the first of the two sessions but were excluded from the continuation. One of these subjects did not follow the instruction not to use self-produced sound except the one from the cane. This had the effect that she always detected the obstacles. The other subject did not seem to be able to use the long cane tapping sounds in a meaningful way. She seemed to respond more or less by chance, and her whole performance showed many signs of insecurity. The significance of these exclusions is further discussed below.

Results and Discussion

The usefulness of long cane tapping sounds alone.

The results (see Table 3) demonstrate that long cane tapping sounds can be used for detection and localization of objects, but there are several indications that these tasks are difficult on the basis of the tapping sounds alone. Already the fact that the experiment was discontinued with two of the originally five subjects indicates this. The behavior of both these subjects may be interpreted as reactions to the difficulty of the task, one reacting with insecurity and the other with the adding of another kind of auditory information.

The difficulty of the task is also indicated by the experimental data. Of totally 240 experimental trials, thus including all canes, obstacle sizes and subjects, there were 18% that resulted in a collision with the obstacle before any detection was made. A further 27% of the

trials ended in a collision with the obstacle during the localization phase, thus after a report of detection. There was thus a collision with the obstacle in 45% of the cases (see Table 4). It should also be observed that false reports of objects appeared during 40% of the totally 60 blank trials. (Some of the standard deviations for the inverted localization distances in Tables 3 and 4 are exceptionally large. This is however an effect of the operation of inversion).

Insert Tables 3 and 4 about here

The effect of obstacle size

As shown in Table 4 the size of the obstacle had an effect on its detection and localization. The effect of obstacle size was confirmed, by analysis of variance for the detection distances, $p<.05$, and was not far from being significant for the inverted localization distances, $p<.10$ (see Table 5). The most interesting aspect of this relation between obstacle size and the two dependent variables is that it strengthens the interpretation of the results as indicating that long cane tapping sounds can be used for detection and localization, even if it is a difficult task.

Insert Table 5 about here

Collisions change to a large extent according to what could be expected from physical considerations, i.e. decreasing with increasing obstacle size with the exception of the largest object. This object also deviates from the general tendency concerning the detection distances (but not concerning the inverted localization distances). The

deviating results for the largest object, which is found for each subject (Figure 4), were not further analyzed, but they may be related to some special acoustical conditions of the experimental room.

Insert Figure 4 about here

Differences between the canes

Analysis of variance, fixed model, for both detection and inverted localization distances did not show any significant differences between the canes (Table 5), The large variation between the canes in the number of collisions (6 - 16 collisions, i.e. 25 - 67%) should be observed, however.

The relation between behavior and spectral content

The canes did not differ between themselves for any of the stopping distances. It was therefore not meaningful to perform a correlational analysis between the performance of the participants and the spectral content of the tapping sounds. The most likely interpretation, however, of the result that canes widely differing in spectral content did not differ in their usefulness for echolocation is that these variations are of slight importance for the detection and localization of objects. This is in line with Wilson's (1967) proposal that no particular region of the spectrum is necessary for echolocation at shorter distances and with a similar conclusion reached by Small and McClellan (1963) in connection with time separation pitch.

This deemphasis of the spectral content is in agreement with a study of the long cane made by Walraven (1982), who, from partly different aspects, considered the absolute values of the frequency spectra

as less important than the variation in the spectra, occurring when the cane is tapped on different materials (cf. also Ungar, 1978).

It should also be remembered that the spectral analysis was done on sounds produced in a semi-anechoic room, while the behavioral studies were done in a much larger room without any special sound-absorbing arrangements. This probably caused many reflections, that may have masked important acoustic differences between the canes.

Differences between the subjects

For both the detection distances and the inverted localization distances the differences between the blind subjects were the strongest of the significant effects, $F(2, 120) = 15.97$ and $F(2, 120) = 3.90$, respectively (see Table 5). This means that the observers stopped at various distances from the objects and is a further indication that blind persons are differently proficient at using echolocation.

Conclusions

The use of echoes of long cane tapping sounds for the detecion and localization of objects is a possible, but difficult task. The size of the object to be detected is important, and the observers differ widely in their proficiency of using echolocation. The different canes and the spectral contents of their tapping sounds does not seem to be essential. A further experimental analysis of the sound factors that determine the usefulness of sounds for echolocation would best be made by a study of synthetic sounds with a systematic variation of different stimulus variables.

Acknowledgements

This study was made possible by a research grant to the second author from the Bank of Sweden Tercentenary Foundation (Dnr. 75:116). Valuable advice and assistance concerning the acoustic aspects of the study was generously given by Mr. Rolf Ingelstam, then at the Department of Technical Audiology, the Karolinska Institute, Stockholm. The following persons were also helpful in different ways: Dr. Lars Bäckström, Dr. Alf Gabrielsson, Mr. Christer Nilebring, Dr. Jan Vegelius and Mr. Kurt Vikman, Department of Psychology, University of Uppsala as well as Dr. Björn Hagerman, Department of Technical Audiology, the Karolinska Institute. The digital frequency analyzer was provided by the Bruel and Kjaer Company. The audiometric tests were performed at the AMU-centre, Uppsala.

References

Ammons, L.H., Worchel, P. & Dallenbach, K.M. (1953). "Facial vision": The perception of obstacles out of doors by blindfolded and blindfolded-deafened subjects. *The American Journal of Psychology, 66*, 519-553.

Ayrapetyants, E.Sh. and Konstantinov, A.I. (Eds.) (1974). *Echolocation in nature.* Arlington, Virginia: Joint Publications Research Service.

Bassett, I.G. & Eastmond, E.J. (1964). Echolocation: measurement of pitch versus distance for sounds reflected from a flat surface. *Journal of the Acoustical Society of America, 36*, 911-916.

Bilsen, F.A. (1968). On the interaction of a sound with its repetitions. Doctoral dissertation, Delft University of Technology, the Netherlands.

Bilsen, F.A. & Ritsma, R.J. (1970). Some parameters influencing the perceptibility of pitch. *Journal of the Acoustical Society of America. 17*, 469-475.

Cotzin, M. & Dallenbach, K.M. (1950). "Facial vision": the role of pitch and loudness in the perception of obstacles by the blind. *American Journal of Psychology, 63*, 485-515.

Fourcin, A.J. (1965). The pitch of noise with periodic spectral peaks, In: Commins D.E., (Ed.) *Rapport 5^{e} Congrès International d´Acoustique* vol 1a, paper B.42 Liège: Imprimerie Georges Thone.

Griffin, D.R. (1977). Echolocation and its relevance to communication behavior. In Sebeok, T.A. (Ed.) *How animals communicate.* Bloomington: Indiana University Press, pp. 252-262.

Hill, E. & Ponder, P. (1976). *Orientation and mobility techniques. A guide for the practitioner.* New York: American Foundation for the Blind.

Jansson, G. (1975). *The detection of objects by the blind with the aid of a laser cane.* (Uppsala Psychological Reports, No. 172). Uppsala: University of Uppsala, Department of Psychology.

Jansson, G, & Schenkman, B (1977). *The effect of the range of a laser cane on the detection of objects by the blind.* (Uppsala Psychological Reports, No. 211). Uppsala: University of Uppsala, Department of Psychology.

Johnson, S.C. Hierarchical clustering schemes. (1967). *Psychometrica, 32*, 241-254.

Small, A.M. Jr. & McClellan, M.E. (1963). Pitch associated with time delay between two pulse trains. *Journal of the Acoustical Society of America, 35*, 1249-1255.

Supa, M., Cotzin, M. & Dallenbach, K.M. (1944). "Facial vision": the perception of obstacles by the blind. *American Journal of Psychology, 57*, 133-183.

Thurlow, W.R. & Small, A.M. Jr. (1955). Pitch perception for certain periodic auditory stimuli. *Journal of the Acoustical Society of America, 27*, 132-137.

Twersky, V. (1951). On the physical basis of the perception of obstacles by the blind. *American Journal of Psychology, 64*, 409-416.

Ungar, E.E. (1978). Sound and vibration characterization of canes for the blind. *Bolt, Bernaek and Newman Inc.*, Cambridge, Massachusetts, Report 3965.

Walraven, J. (1982). *Tast- en steunstokken voor visueel gehandicapten; een inventarisatie en evaluatie van functionele, ergonomische en mechanische aspekten.* (The cane as a mobility aid for the visually handicapped; an inventory and evaluation of functional, ergonomical and mechanical aspects). (Report IZF 1982 C-15) Soesterberg, The Netherlands: Institute for Perception TNO.

Wilson, J.P. (1967). Psychoacoustics of obstacle detection using ambient or self-generated noise. In Busnel R.-G. (Ed.) *Animal Sonar Systems. Biology and Bionics.* Jouy-en-Josas, France, pp. 89-114.

Worchel, P. & Dallenbach, K.M. (1947). "Facial vision": Perception of obstacles by the deaf-blind. American Journal of Psychology, 60, 502-553.

Yost, W.A., Hill, R. & Perez-Falcon, T. (1978). Pitch and pitch discrimination of broadband signals with rippled power spectra. Journal of the Acoustical Society of America. 63, 1166-1173.

Appendix: Some methodological control experiments

The same experimental setup was used as the one described above for the spectral analysis. (An exception is noted below). The purpose of these tests was to study the effect of some methodological variables on the properties of long cane sounds.

Integration time

The frequency analyses produced by different integration times, 1/32, 1/16, 1/8, 1, 2 and 4 sec were compared. An increased integrating averaging time gave lower readings on all frequency bands. The relations between the bands were very similar for the various times, with some discrepancies at the higher bands. The diagrams of the shorter times were more or less identical to those of a longer time, except that the amplitudes of the shorter times had been added by a constant for each frequency band. The discrepancies at the higher bands is not likely depending on the room, but on the shorter durations of these vibrations. This test was made with a 50 mm thick concrete plate, covering the tapping area.

Sound duration

In order to study in some detail the temporal structure of the sound, oscilloscope tracings of the sounds of 17 of the 32 canes were studied. A Bruel and Kjaer Frequency Analyzer, type 2107, was used as an amplifier for the signal from the microphone. This signal was fed to a Tektronix oscilloscope, type 565, and its screen was photographed with an oscilloscope-camera. The sounds of the canes that were tested decayed within 5 - 10 msec to at least -18 dB of the highest transient. These measurements made on linoleum thus confirm that it is reasonable to use a short integration-time.

Incident angle between cane and ground

Varying the incident angle of the cane to the ground by small shifts (0-10°, 30°) made no systematically different sound spectra as compared to the standard of 45°. However, if the incident angle was put at 90°, i.e. the cane bounced up and down in a vertical fashion, this had a high impact on the frequencies. These effects may be explained by postulating two different ways of producing the sound by a cane. However, as a blind person would most likely never use the long cane as a vertical rod, this mode of sound-production is of little interest.

Handgrip

In our experiment the cane was held lightly between thumb and index finger. In the ordinary technique of manipulating the cane, the blind person holds it tightly in the hand, with the index finger, or sometimes the thumb, pointing down the cane (Hill and Ponder, 1976, p. 53). This technique is expected to damp the vibrations of the cane. When testing for differences between the undamped technique used by us and the recommended technique for the blind we found them to be very similar to each other concerning the sound spectra.

Tappings by different persons

Tests were done to find out if two different persons produced about the same frequency spectrum when the canes were tapped. Tests on several canes showed only small differences (<3dB) between persons, for any 1/3 octave-band on the Bruel and Kjaer Digital Frequency Analyzer, type 2131.

Reliability of the spectral analysis

The reliability of the tests was high, as frequency analyses of the same type conducted on different occasions were nearly identical.

Table 1

Mean SPL-values of all the 32 canes at each 1/3 octave band. (The deviation of each of the 10 canes used in the experiment from the means of all the 32 canes is depicted in Figure 2).

Octave band Center frequency (kHz)	SPL (dB)	Octave band Center frequency (kHz)	SPL (dB)
.250	46	2.5	55
.315	43	3.15	56
.400	43	4.0	56
.500	41	5.0	56
.630	43	6.3	55
.800	42	8.0	52
1.0	43	10.0	50
1.25	47	12.5	48
1.6	51	16.0	45
2.0	54	20.0	44

Table 2

A description of the canes used in the experiment

Cane No.	Manufacturer or distributor	Material of tip	No. of parts of cane, tip excluded	Length of cane (m), tip included	Remarks
1	Research Inst. Swedish Nat. Defense	nylon	3	1.25	one-beam laser cane
2	G. Christensson, Sweden	nylon	5	1.21	
3	- " -	steel	5	1.21	identical to cane no. 2, except for tip
4	DBF Sales Co., Sweden	plastic	5	1.36	telescopic type of cane
5	Special Teknisk Mat. Ind., Denmark	nylon	1	1.35	
6	- " -	nylon	3	1.31	
7	Royal Nat. Inst. Blind, England	nylon	2	1.35	
8	Amer. Found. Blind, USA	nylon	6	1.33	Hycor cable cane; TRS-437[a]
9	- " -	nylon	1	1.36	Equipoise cane; TRS-357[a]
10	- " -	steel	4	1.36	Mahler Heavy Duty cane; TRS-307[a]

[a] Trade nos. refer to Products for people with vision problems, New York: American Foundation for the Blind, 1979

Table 3

Mean detection and inverted localization distances for each cane and number of collisions during the detection and localization phases, respectively, (n=24).

Cane No.	Detection distance (m)		Inverted localization distance (m^{-1})		No. collisions		
					Detection phase	Localization phase	Total
	M	SD	M	SD			
1	4.70	4.06	1.56	.40	3	5	8
2	4.11	4.18	4.33	10.89	3	3	6
3	3.20	3.73	1.07	2.52	7	2	9
4	3.74	4.02	1.23	3.15	5	11	16
5	2.44	3.23	5.70	19.92	7	5	12
6	3.28	3.55	1.33	2.93	6	7	13
7	2.92	3.45	1.85	4.57	4	10	14
8	3.92	3.93	1.23	2.70	1	7	8
9	3.23	3.60	1.57	2.84	3	9	12
10	4.32	4.33	1.00	2.56	3	5	8
Overall mean	3.59	-	2.09	-	4.2	6.4	10.6

Table 4

Mean detection and inverted localization distances for each obstacle size and number of collisions during the detection and localization phases, respectively (n=60).

Obstacle size (m^2)	Detection distance (m)		Inverted localization distance (m^{-1})		No. collisions		
					Detection phase	Localization phase	Total
	M	SD	M	SD			
.188	3.05	3.63	.31	.85	21	21	42
.376	3.61	3.90	1.23	3.89	12	23	35
.752	5.13	4.34	3.13	7.43	2	8	10
1.504	2.56	3.03	3.64	12.95	7	12	19
Overall mean	3.59	-	2.08	-	10.5	16.0	26.5

Table 5

Analysis of variance, fixed model, for each of the dependent variables

A. Detection distances

Source	df	MS	F
Obstacles (O)	3	74.64	5.67[a]
Subjects (S)	2	210.24	15.97[a]
Canes (C)	9	11.52	.87
O x S	6	6.28	.48
O x C	27	10.50	.80
S x C	18	16.79	1.28
O x S x C	54	12.14	.92
Within	120	13.17	

B. Inverted localization distances

Source	df	MS	F
O	3	148.40	2.50[b]
S	2	201.40	3.39[a]
C	9	59.28	1.00
O x S	6	115.20	1.94
O x C	27	57.07	.96
S x C	18	62.98	1.06
O x S x C	54	53.76	.90
Within	120	59.39	

[a] $\underline{p} < .05$ [b] $\underline{p} < .10$

Figure captions

Figure 1. The microphone arrangement in the sound absorbing chamber. Distances in meters. The angle between the microphone and the vertical part of the stand was about 52°.

Figure 2. Deviations in SPL for the 10 selected canes from the average SPL of all the 32 canes at different 1/3 octave bands.

Figure 3. Experimental arrangement, showing one rack with an object. After Jansson (1975).

Figure 4. Mean detection distances for each subject at the four object sizes.

FIGURE 1

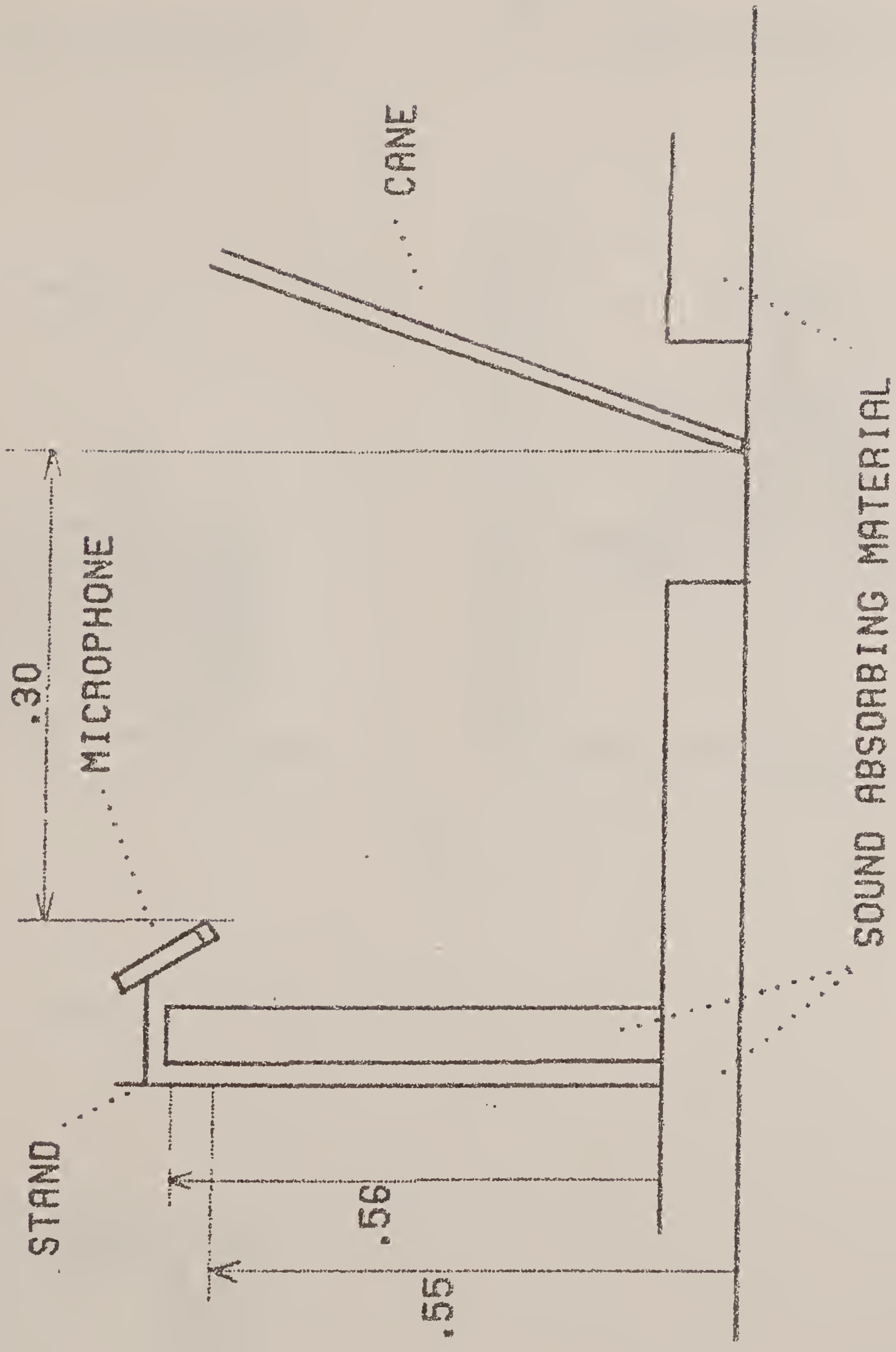
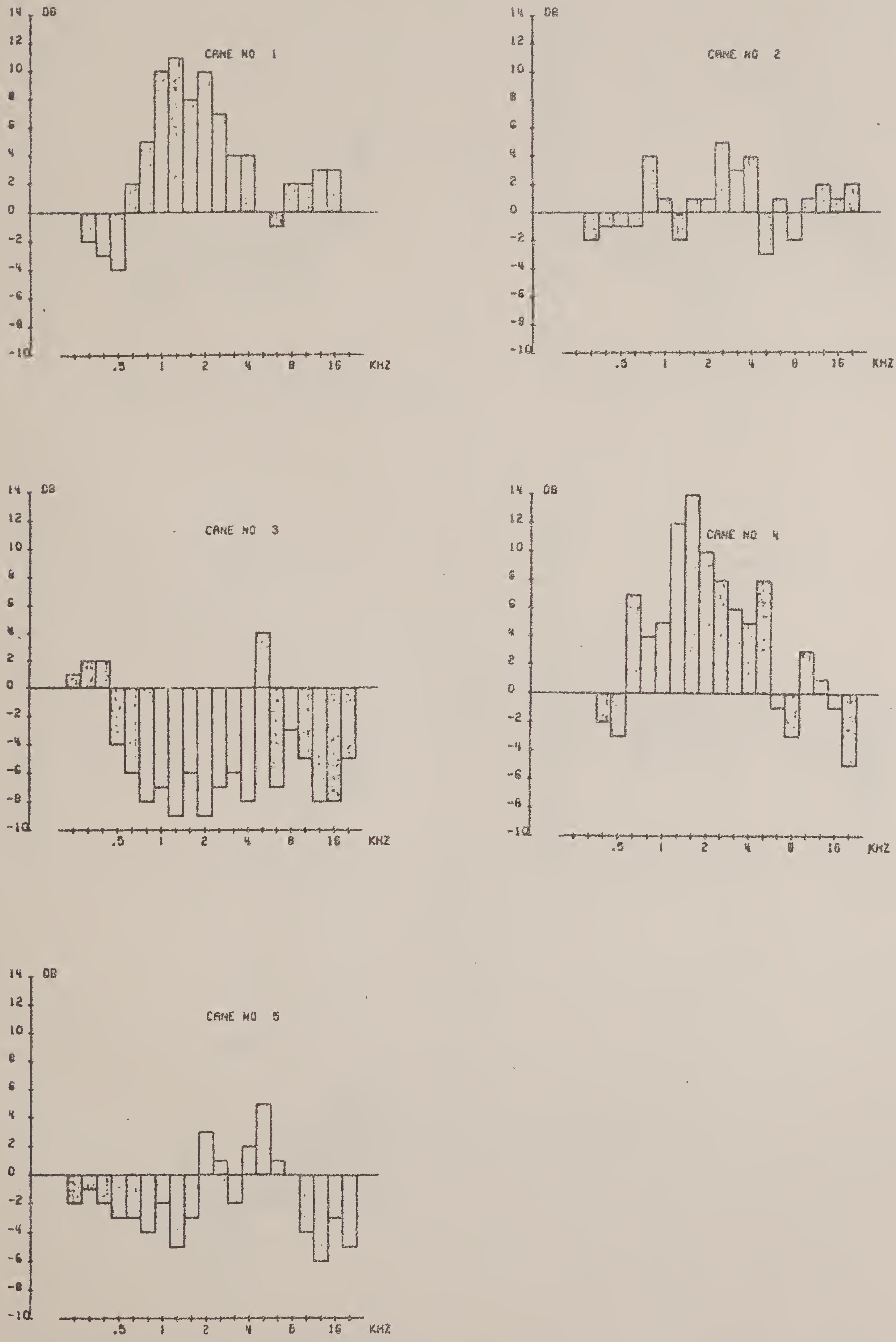
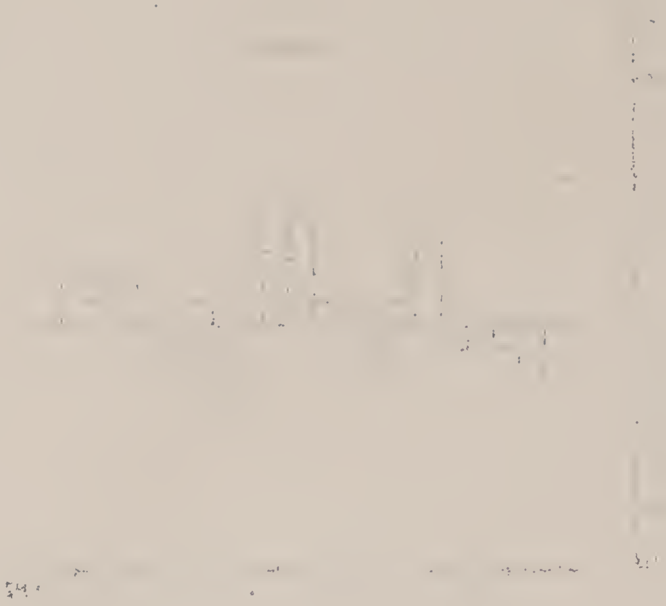
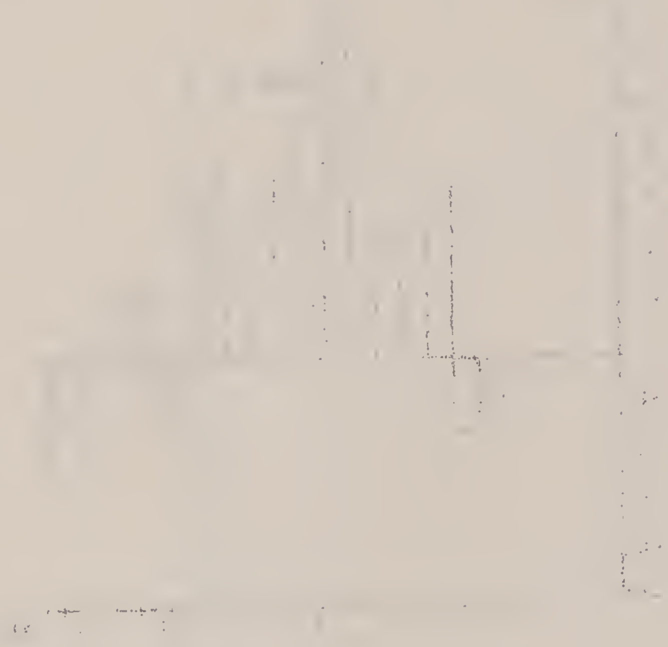
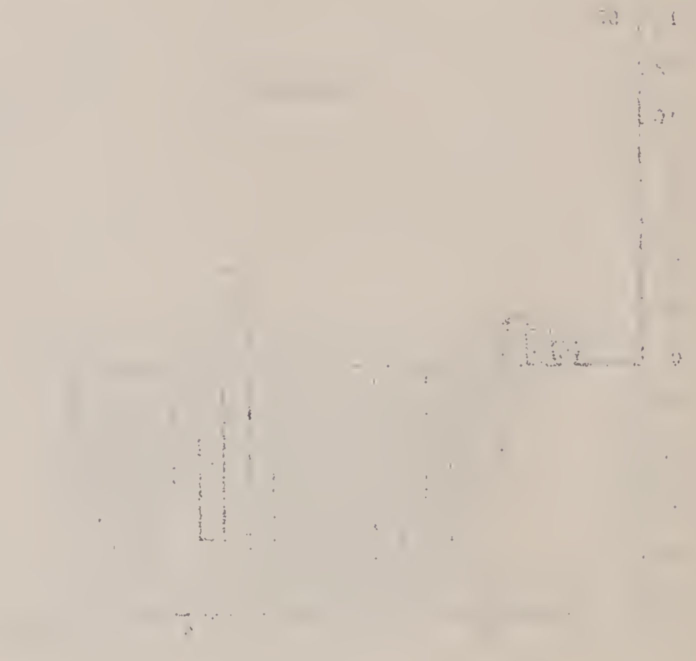


FIGURE 2 (1)


CANE NO 1
CANE NO 2
CANE NO 3
CANE NO 4
CANE NO 5
DB
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
.5
1
2
4
8
16
KHZ







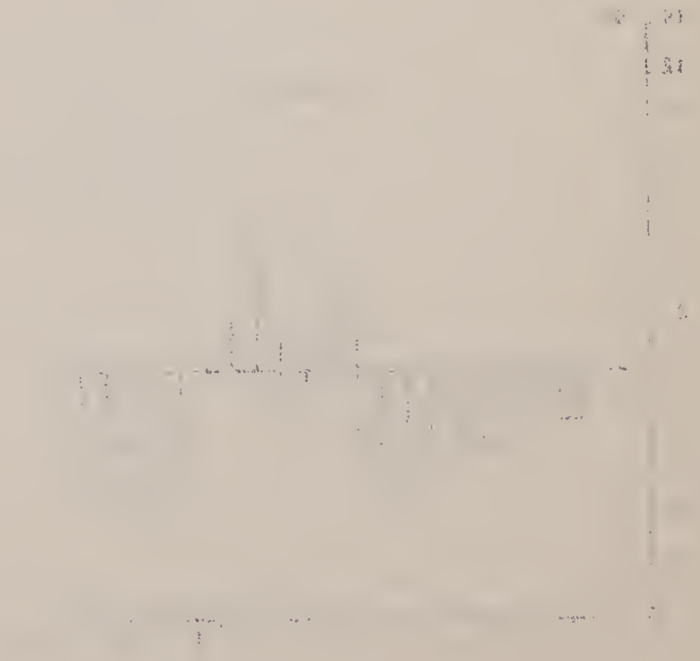
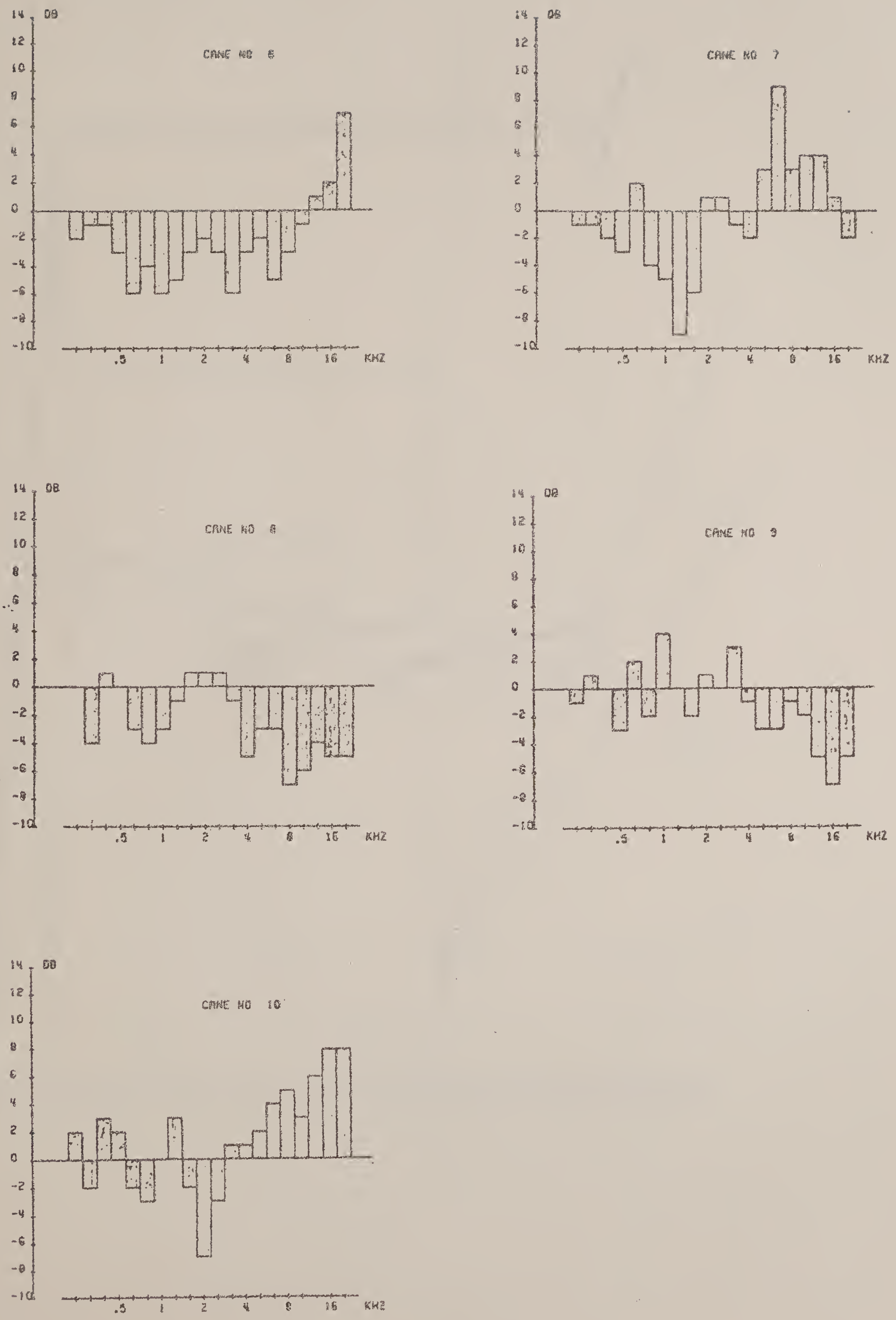
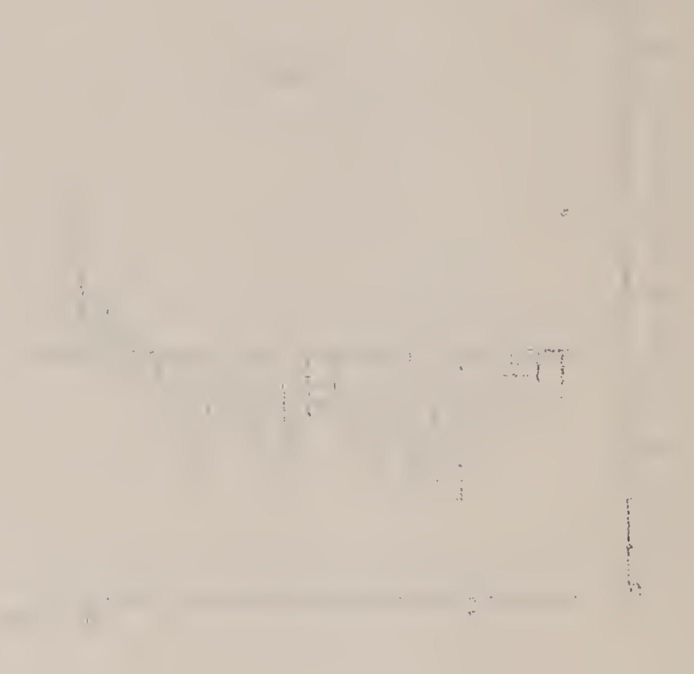
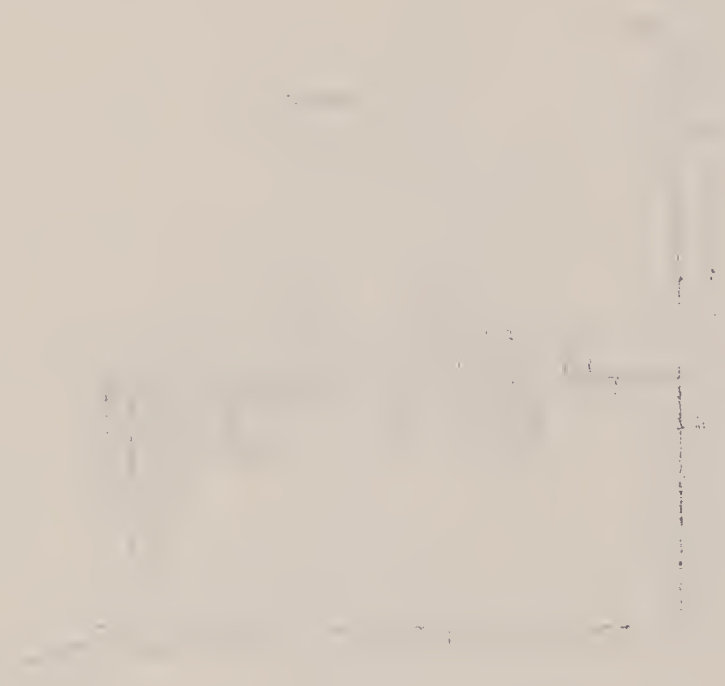
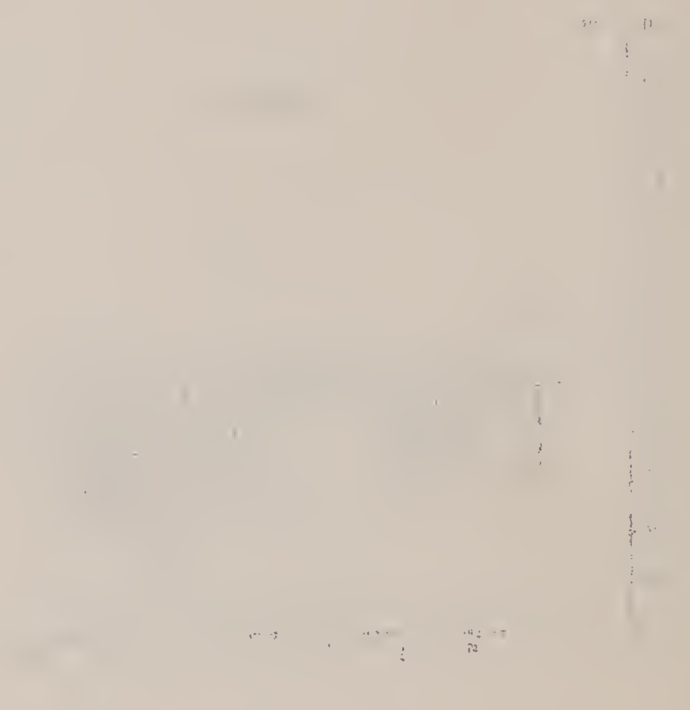


FIGURE 2 (2)


CANE NO 6
CANE NO 7
CANE NO 8
CANE NO 9
CANE NO 10
DB
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
.5
1
2
4
8
16
KHZ







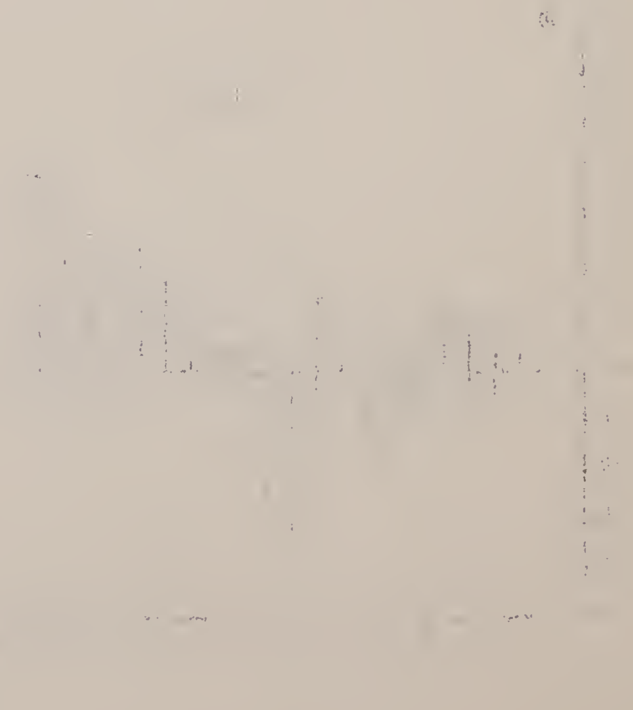


FIGURE 3

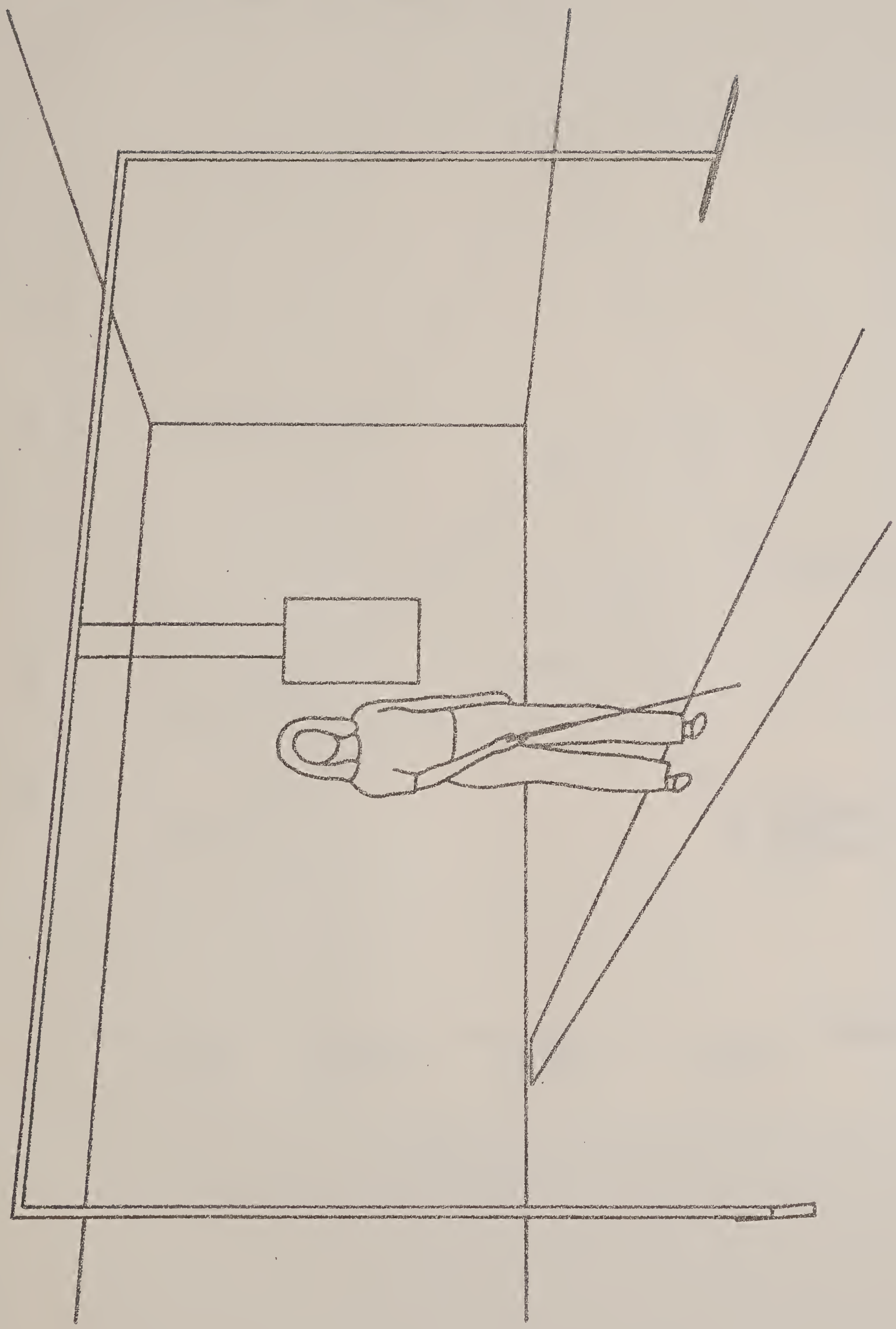
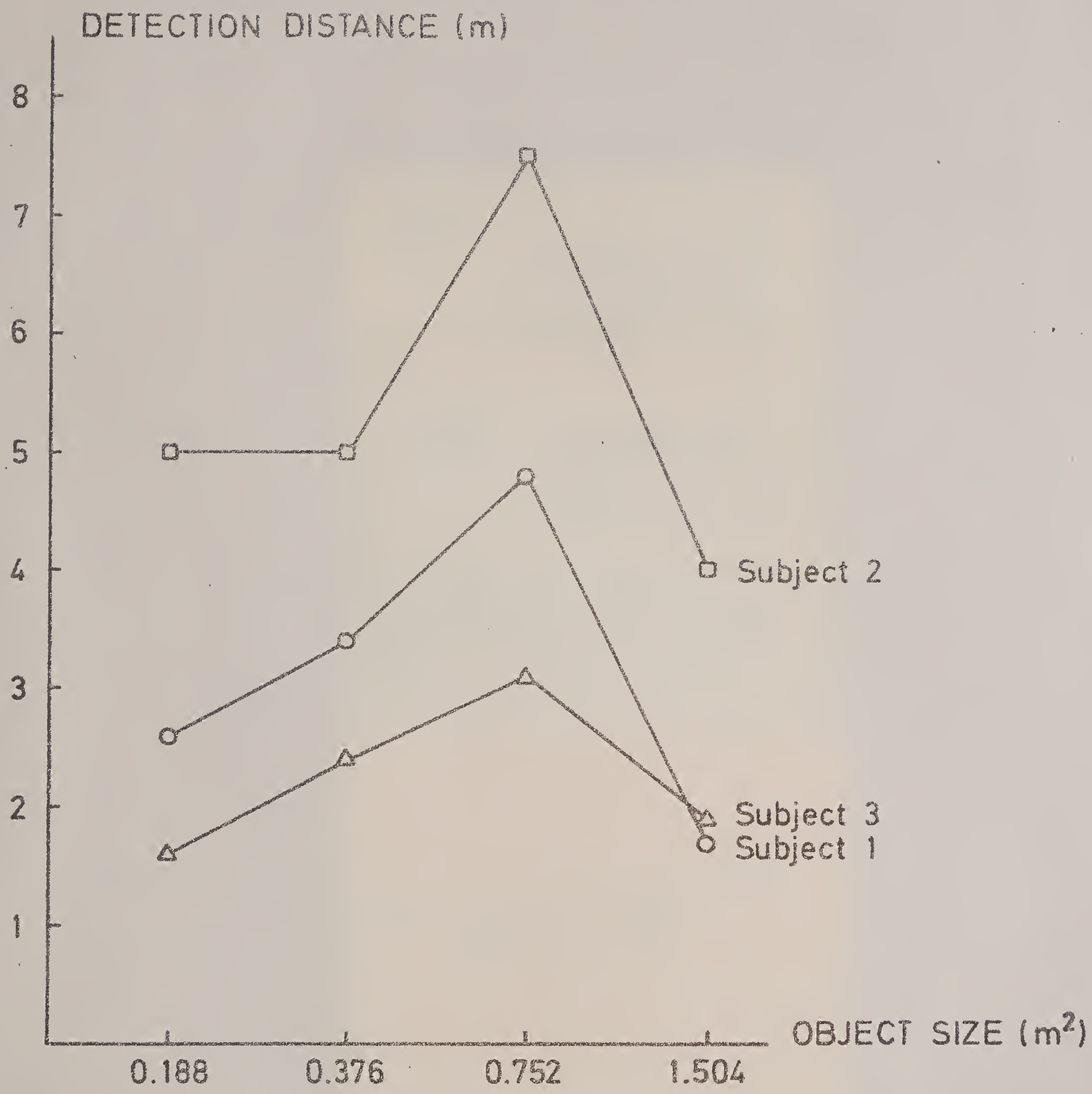
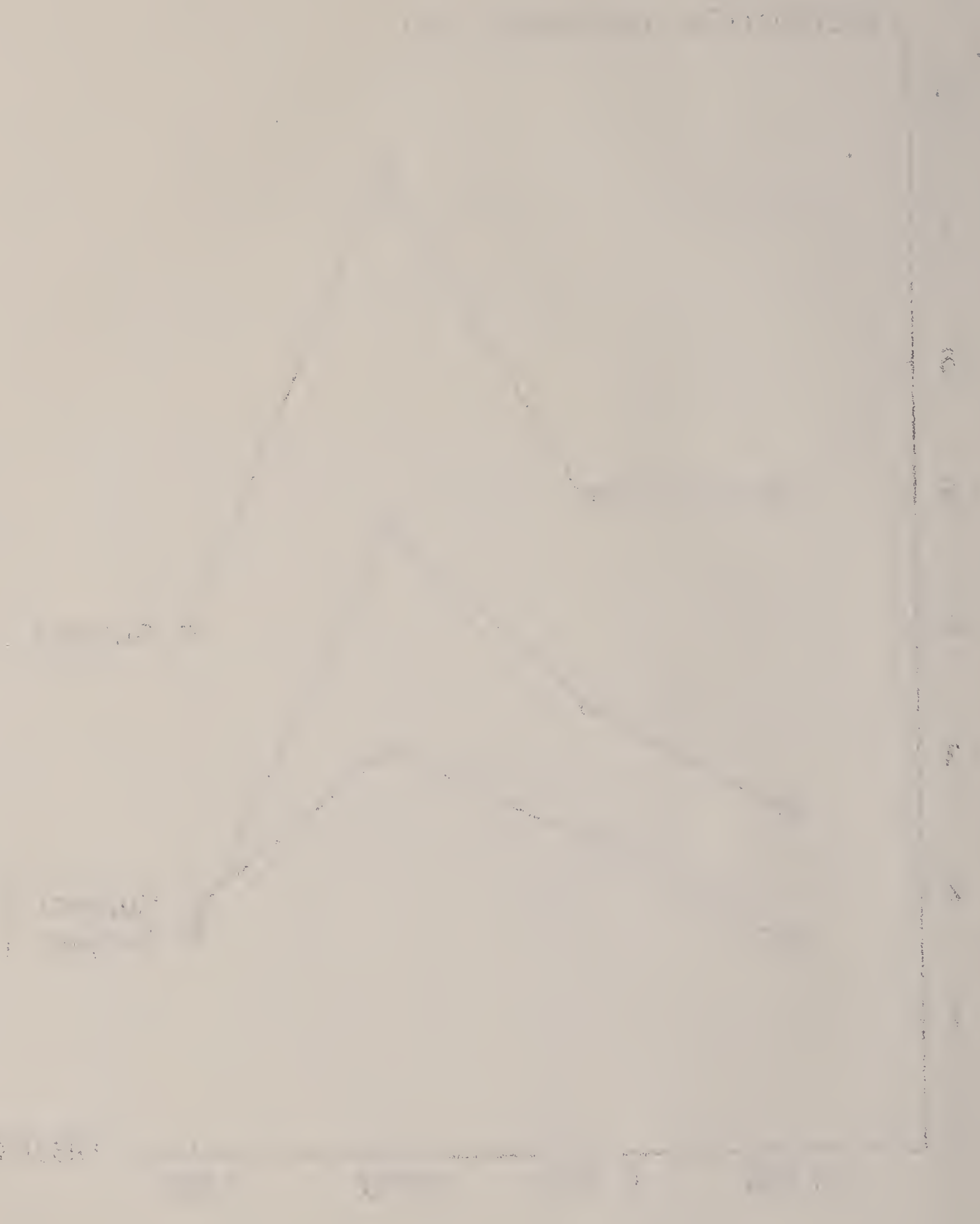


FIGURE 4


DETECTION DISTANCE (m)
8
7
6
5
4
3
2
1
OBJECT SIZE (m^2)
0.188
0.376
0.752
1.504
Subject 2
Subject 3
Subject 1



HV1708
Sch27 Schenkman, Bo and
The detection
and localization
of objects by the

DATE DUE

HV1708
Sch27 Schenkman, Bo
The detection
and
localization of

DATE	ISSUED TO
~~6/22~~	~~Adele Piontnica 1440 50th st. 436-1474~~

AMERICAN FOUNDATION FOR THE BLIND
15 WEST 16th STREET
NEW YORK, N.Y. 10011